Space Weather Technical Forecast

Issued on Wednesday 25 December 2024 at 12:00 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: R1/R2 Expected throughout. G1/G2 Likely in next 24 hours from inbound CME.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Activity measured at GOES16 has been Moderate, with several M-class flares observed, mostly from the complex of spots near south-centre disc, however the peak flare measured at M4.9 and was observed from AR3938 in the northeast at 25/0444UTC.

There are now up to eleven sunspot regions on the disc, with AR3930 no longer visible on the southwestern horizon, AR3929 fading to plage, and with a new unnumbered group hoving into view over the southeastern horizon that currently appears unipolar. The most-changed regions on the disc included AR3938 in the northeast, which saw strong areal growth in its northern intermediate spots to present as a Dai/Beta. AR3933 near centre-disc showed proliferation in its intermediate portions as an Eki/Beta-Gamma, which was matched at the same longitude by development in trailing spots in AR3928 (a Dsi/Beta-Gamma-Delta) to its immediate south, the latter of which perhaps also including a tenuous Mt Wilson delta in its easternmost spots. AR3932 in the southeast showed the reverse trend, with areal decay throughout its Eki/Beta-Delta classification - especially in its leading group - although the eastern penumbra does perhaps also still contain a weak Mt Wilson delta. All the unipolar groups were unchanged on the disc, aside from AR3934 in the northeast, which consolidated and faded in the period.

A Type II radio emission with an estimated speed of 1064km/s was observed at 25/0447UTC. This was almost concurrent with the peak flare of the period from AR3938, however recent coronagraph imagery instead suggests a large and fast CME from the southeastern limb is perhaps the most likely culprit, with up to three CME 'lobes' evident from this location or from the far side.

Faint partial haloes first visible on corongraph imagery 25/0430UTC apparently heading mainly south and southeast have also been tentatively linked with the far side and not concurrent front-sided flare activity, although triangulating STEREO A imagery of the ejecta for the relevant period is very faint.

GONG H-Alpha for the period is intermittent, however the cohort of filaments that started the 24-hour period appear to still be in place, further implying along with GOES SUVI 304 imagery that

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there have been no significant Earth-directed events. Current thoughts are therefore that no new Earth-directed CMEs are en route.

Solar Wind / Geomagnetic Activity: Solar winds, as observed at L1 by ACE, showed a waning connection to CH01/-. The solar wind speed fell from Elevated levels in the upper-500s of km/s to reach Slightly Elevated levels in the upper-400s by the period's end. The solar wind density showed a concurrent rise within normal background single figures ppcc, which is perhaps the resumption of the ambient wind density. The IMF was at typical levels, with a level peak near 6nT and with an erratic north-south component between the confines of +/-5nT. The phi angle was negative (towards the Sun) throughout.

The net result of the above solar wind measures was for provisionally Quiet to Unsettled Kp indices, peaking at '3+' in the 21-24UTC interval.

Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV) showed a continuing gradual decline from an event on 19 December, with the current 24-hour period seeing an early 'peak' near 2pfu, i.e. below the S1/Minor Radiation Storm threshold.

High energy electron flux (greater than 2MeV) observed by GOES16 was at Moderate levels, with the past 24 hours seeing a peak at 24/1605UTC near 800pfu. The associated 24-hour fluence was below the Active (1e8 integrated flux) threshold on a slightly declining trend. The 25/0001UTC observation was 2.69e7 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Further M-class flares are Expected, with a Slight Chance of isolated X-class flares throughout. No significant regions are due to depart the disc, however the oncoming southeastern limb may yet warrant a revision of the daily risk when any regions here become more visible.

Solar Wind / Geomagnetic Activity: A CME from 23 December may give a glancing blow at Earth on Day 1 or Day 2 (25-26 December), with some uncertainty in the timing of this feature. No other CMEs currently feature in the forecast, although confidence in this aspect of the forecast is lower than usual. Solar winds are elevated but slowly declining due to a waning connection to CH01/-.

Geomagnetic activity is expected to be mainly Quiet to Unsettled at first. Later Day 1 into Day 2, peak G1-G2/Minor-Moderate Storm levels are Likely, with a Slight Chance of G3/Strong Storm intervals, due to potential CME influence. By Days 3 and 4 (27-28 December), mainly Quiet to Unsettled activity is forecast, but with lower confidence given the uncertainty in the CME forecast.

Energetic Particles / Solar Radiation: There is a Slight Chance of S1/Minor Radiation Storm or greater enhancements during the period. In the absence of any further notable flares, ongoing slightly enhanced high-energy proton counts should ease towards Background levels in the coming days.

The high energy electron forecast carries lower than average confidence due to the uncertainty in the CME forecast. However, there is a chance of exceeding Active on Day 1, before any CME arrival,

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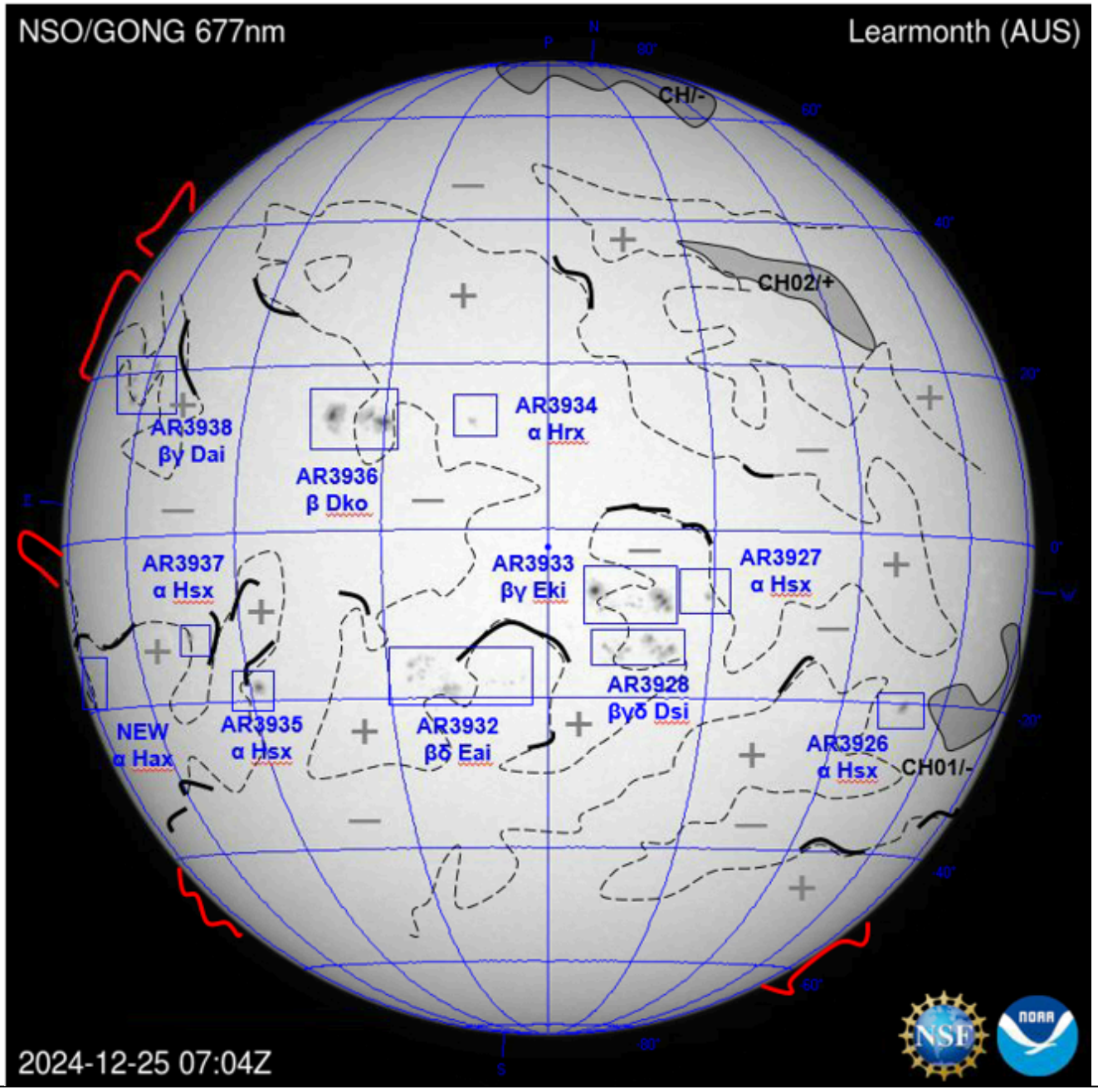
reducing to a slight chance on Days 2-3 (26-27 December). This level may then increase a little by Day 4 (28 December) as dynamic pressure from any CME influences eases.

Figure 1: Solar synoptic map, valid 25/0704UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms

There are two threads to the current geomagnetic forecast - the first and more significant a CME generated by the M8.9 flare from AR3923 and a nearby, sympathetic filament lift-off in the southeast disc. The bulk of the ejecta is modelled to pass below the Earth-Sun line, however a glancing blow is considered possible on Day 1 or Day 2 (25-26 December). ACE EPAM LEMS is showing a slight rise in teh past 24 hours, although the rate has slowed which perhaps implies any imminent or early arrival is not likely. Uncertainty in the timing of this feature is increased by Enlil showing a High Speed Stream (HSS) at the same time, with no significant source coronal hole visible in GOES SUVI 195 imagery. That said, there is the possibility of a coronal hole obscured by magnetic looping north of the AR3933/AR3928/AR3932 complex. No other Earth-directed CMEs currently feature in the forecast, however due to the number of recent CMEs in solar imagery, confidence in this aspect of the forecast is lower than usual.

The second part of the forecast concerns coronal holes. Solar winds are elevated but slowly declining due to a waning connection to CH01/-. A further enhancement is possible, but unlikely on Days 2 and 3 (26 and 27 December) from CH02/+ located in the northwest disc. However, as discussed above, there is also the possibility of an obscured coronal hole giving a HSS as modelled by Enlil, but perhaps slightly later in the period.

Overall, geomagnetic activity is expected to be mainly Quiet to Unsettled at first. Later Day 1 into Day 2, peak G1-G2/Minor-Moderate Storm levels are possible, with a Slight Chance of G3/Strong Storm intervals, due to potential CME influence. By Days 3 and 4 (27-28 December), mainly Quiet to Unsettled activity is forecast, but with lower confidence given the uncertainties.

Geomagnetic Storm	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Minor or Moderate	G1 to G2	No	50	60	10	5
Strong	G3	No	5	10	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

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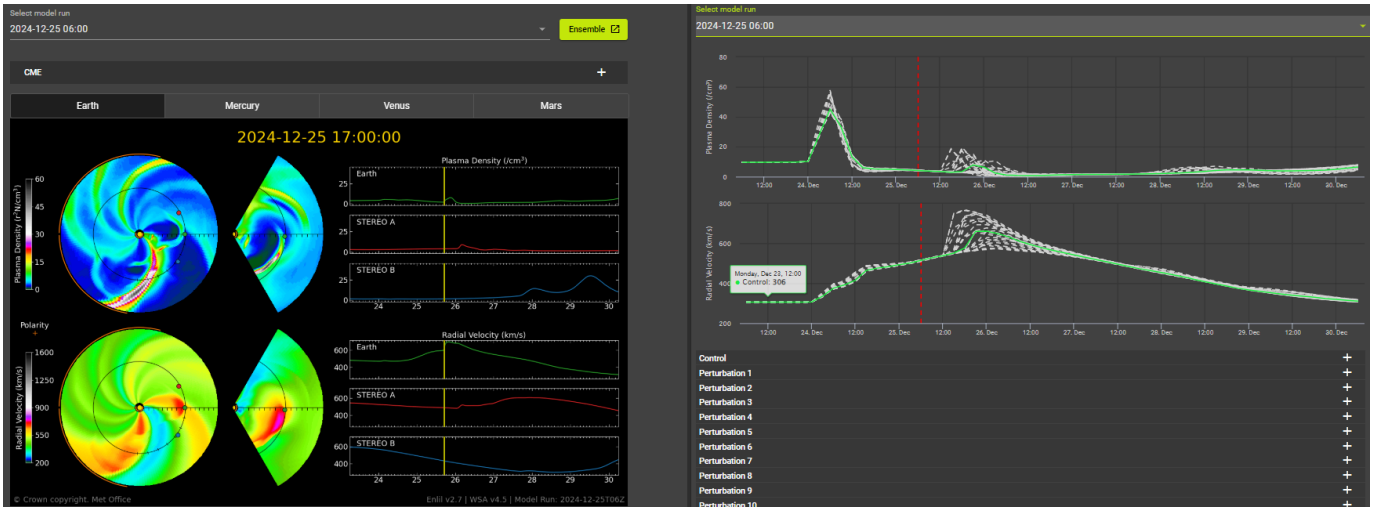
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R⊙ (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed (km/s)	Estimated Arrival Time (UTC)	Comments
23/1550 UTC	Partial	Flare and Filament	SE disc (AR3932)	780	25/1800 UTC	Possible glancing blow, low confidence on timings. +/- 12 hours from Estimated Arrival Time.

Figure 2: Latest MOSWOC Enlil model and ensemble (badge time 25/0600UTC), paused at the 1AU crossing time of the 23 December CME. Some ensemble members show a further glance from a 24 December 0900UTC southeastern quadrant CME, however the deterministic miss is the preferred solution in this later case.



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Radio Blackouts - X-Ray Flares

The Penticton 10.7cm flux is currently on a strong rising trend, reaching a peak for the rotation and rivalling the peak last seen at Hallowe'en. Many of the more complex regions on the disc are exhibiting strong growth and occupy positions near the middle of the disc, making them potential threats for many days yet and more prone to becoming sources for Earth-directed CMEs.

There are signs of a new region rotating onto the southeastern limb, perhaps returning Ex-AR3912, which was previously responsible for X-class flare activity earlier in December and was perhaps the source of a large far-sided CME on 17 December. If the sunspot region has maintained its complexity it could contribute to higher flare probabilities in the upcoming days although far-side sounding imagery does suggest this region may have faded somewhat. No significant sunspot regions leave the disc in the four days.

The assessment of any new regions notwithstanding, flare risk looks to remain elevated during the period and further M-class flares are Expected, with a Slight Chance of X-class flares maintained throughout.

X-Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 (M Class)	Yes	80	80	80	80
Very Active	R3-R5 (X Class)	No	10	10	10	10

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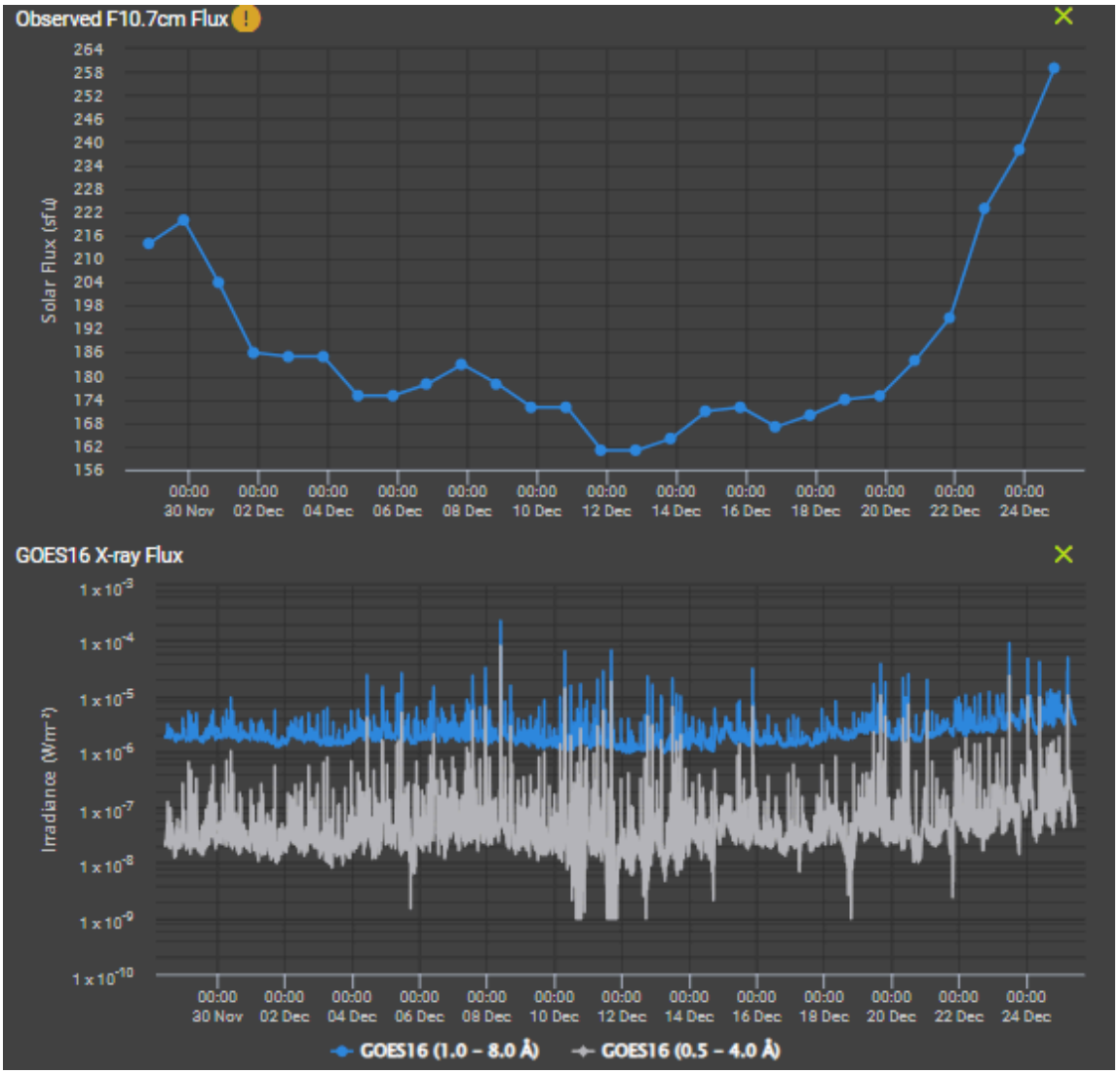
Figure 3: Past rotation's 10.7cm Penticton flux and GOES16 X-ray flux, showing a recent strong upward trend in the proxy for sunspot number, with this trend visible in the upward curve in the X-ray trace towards the right of the plot.



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Solar Radiation Storms (High Energy Protons)

The source of the currently observed slight enhancement in the near-Earth environment is somewhat uncertain, but a far-sided source on 19 December seems most likely. The mechanism for any further enhancement of proton counts would now very likely be independent of this original source.

High energy proton counts are slowly declining and should continue to ease towards typical Background values in the coming days in the absence of significant flaring - the current UTC morning's M-class events are now thought unlikely to offer any uptick in risk in the first 24 hours or so. There remains an unaltered Slight Chance of S1/Minor Solar Radiation storms or greater, should any significant flares occur, this increasingly slightly as the larger regions on the Earth-facing disc move into more favourable western locations for connection with Earth.

Radiation Storms Probability (Exceedance)	Level ($cm^{-2}sr^{-1}s^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	10	10	15	15
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and/or 50 MeV ≥ 10pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

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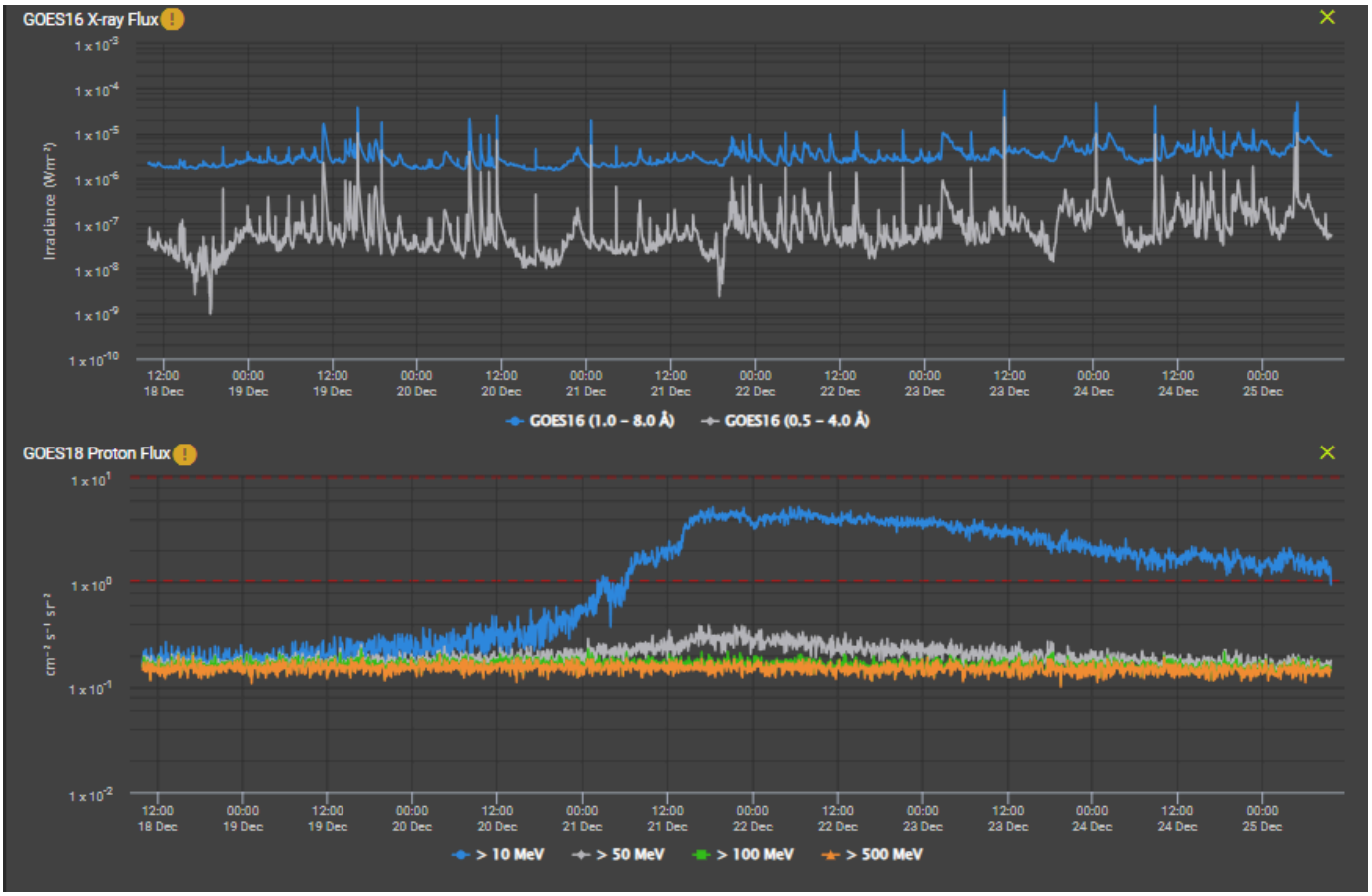
Figure 4: GOES16 X-ray flux and GOES18 high energy proton flux for the past week. The current slight enhancement of 10MeV protons does not readily correlate with the front-side flares, and perhaps relates to a large eastern far-sided event on 19 December.



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High Energy Electrons (≥ 2MeV)

Current high energy electron flux has been at moderate levels in the last 24 hours. As solar wind pressure from CH01/- continues to ease, diurnally high electron flux levels are possible on Day 1 (25 December). However, the likely arrival of a CME later Day 1 or early Day 2 (25-26 December) may temporarily suppress electron counts at GEO, before potentially increasing again later in the period, dependent on intervening geomagnetic activity.

Electron fluence has been slowly declining over the last 24 hours, and is most likely to remain below the Active threshold for much of the period. However, there is a Chance of exceeding Active on Day 1, before any CME arrival, reducing to a Slight Chance on Days 2-3 (26-27 December), this increasing a little by Day 4 (28 December), but with low confidence.

MOSWOC REFM is not likely to completely capture forecast conditions in the period given non-persistent coronal hole fast winds and an inbound CME.

GEO Electron Environment Probability (Exceedance)	Level ($cm^{-2}sr^{-1}$ day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ 1×10^8**	No	30	20	10	30
Very Active	**≥ 2 MeV ≥ 1×10^9**	No	1	1	1	1

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Figure 5: The past week in L1 solar wind speed, GOES16 electrons and geomagnetic activity (Kp measured by BGS). The diurnal oscillation of electrons at GEO has been fairly resilient to recent geomagnetic activity within the Moderate flux bracket, only slightly reducing in the wake of Active geomagnetism late on 23 December, which has at least temporarily scotched an upward response to High flux from CH01's fast wind.

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